October 14, 2016

FCC
445 12 St NW
Washington, DC 20554

RE: Comment toward ET Docket No. 16-191, TAC Noise Floor Technical Inquiry

Dear Technical Advisory Committee Members,

The RadioJove Spectrograph Users Group (SUG) is a group of professional and amateur radio astronomers who work together to study cosmic radio emission in the upper half of the HF band using spectrographs and single-frequency receivers on a 24x7x365 basis.[1]

The Radio Jove project began in 1998 with funding from NASA and is now a self-sustaining, non-profit orginazation.[2] The project's aim is to foster science, technology, and mathematics education by making available low cost single-frequency radio receivers, antenna kits, and educational resources to schools and interested individuals. The Spectrograph Users Group is a subset of more advanced participants within the Radio Jove program.

The data collected by participating observatories spans years to decades. As such, we feel we may be in a unique position to offer input to the question of whether the noise floor has changed in this frequency band, and if so, by how much.

Our interpretation of the noise floor is the noise present across the portion of the spectrum being observed against which cosmic noise sources must be measured. All cosmic radio emissions are noise emission. Therefore, when the noise floor rises, it becomes more difficult unto impossible to detect cosmic noise signals.

[1] For more information about the SUG, see http://www.radiojove.org/SUG/

[2] For more information about the Radio Jove project, see http://radiojove.gsfc.nasa.gov/ and http://www.radiojove.org/

The noise floor in the HF band has two main components: the ever-present galactic background noise and terrestrial noise. The galactic background is always present and immutable.[3] Terrestrial noise is made up of natural noise from lightning and man-made noise from intentional and unintentional radiators. The noise from lightning is not amenable to amelioration. The man-made portion of terrestrial noise, however, is certainly controllable and is the focus of our concern.

Presently the FCC recognizes the importance of radio astronomy by providing this service several allocations across the RF spectrum, among which is an allocation in the upper HF band at 25.55 to 25.67 MHz.[4] We find that this radio astronomy allocation is often violated by unintentional radiators.

Specific answers to your Inquiry follow.

1) From a radio astronomy perspective, there is often a noise floor problem in the upper HF band.
   a) Major sources are power line component leakage, consumer electronics, solar power systems, and cable TV (CATV) broadband internet signals.
   b) Radio astronomy is often severely impacted by the rising noise floor.
   c) Keeping power and CATV transmission and distribution lines and equipment in good working order costs money, as does designing and producing RF-quiet consumer electronics (especially switch-mode power supplies). As such, government regulation and active enforcement is required to prevent pollution of the RF spectrum.
2) The problem exists as follows:
   a) Spectrally from 15 to 32 MHz and far beyond in both directions.
   b) Spatially
      i) Indoor vs outdoor makes little difference in the HF band
      ii) Cities have a horrible noise floor problem due to many intentional and unintentional radiators. Rural settings are sometimes better, but are still prone to an elevated noise floor due to the proliferation of cheaply-designed consumer electronics.

[3] See Appendix 1 for a description of the galactic background in the upper HF band.
[4] 47 C.F.R. § 2.106, 31 Aug 2016.

iii) Across short distances of a few dozen to a hundred miles, the noise floor is most often higher with proximity to the radiator. However, propagation effects can cause communications signals, HF radar, and distant lightning to elevate the noise floor for observers many hundreds to thousands of miles away.

iv) Propagation effects can be easily observed in a 24-hour spectrogram and are therefore very easy to account for. See Appendix 2 for examples.

c) Temporally

i) The daytime noise floor is always elevated due to natural propagation effects and the human desire to operate electronic devices not normally used when sleeping. On the other hand, power line and CATV noise shows no such daily cycle.

ii) There does not appear to be a strong seasonal change in the noise floor in the upper HF band.

3) We are unaware of any published quantitative multi-year or multi-decadal studies of the absolute noise floor in the upper HF band.

a) In our experience, interfering noise becomes harmful to HF radio astronomy when it is stronger than -10 dB relative to the galactic background emission at the frequency of interest. Noise stronger than this makes HF radio astronomy progressively less feasible. By the time the noise level reaches and exceeds the galactic background level, HF radio astronomy becomes impossible.

b) Radio spectrograph and single-frequency records spanning the last two decades exist for the upper HF band. Noise floor contributors are identifiable as each has a relatively unique signature visible in a spectrogram of the band of interest.

c) We are unaware of any scholarly articles or other sources of information about recent trends in the noise floor in the upper HF band.

4) A noise floor study can be performed by continuously recording the band of interest with a radio spectrograph.

a) The focus of the study should be on the relative flux density of the man-made radio emission in relation to the natural galactic background emission.

b) Government funding is preferable; otherwise, it will never get done.

c) Continuous recording the suitably time-averaged RF spectrum and comparing the resulting daily data sets over time is the method to use. This method necessitates long term preservation of data so that such historical and retrospective studies can be performed. Recording, retention, and analysis of the data require sustained commitment and financial support.

d) The noise floor should be measured as follows.

   i) Optimal instrumentation would be a wide band antenna and a radio spectrograph.

   ii) Measurement parameters are time, frequency, and signal amplitude.

   iii) The spatial scale may be omni-directional and the temporal scale may be on the order of one second. Equipment design could be refined to provide directional capability at higher cost.

   iv) The instrumentation could be made to sweep a directional antenna around the horizon once every minute. This would be useful to determine the relative direction of radiators impacting the noise floor.

   v) The optimal height above ground is that used for the service in question. For HF radio astronomy, an antenna height of 10’ to 25’ would work.

e) The recommended accuracies are 1 second temporally, 10 kHz spectrally, and 0.5 dB in amplitude.

   i) Sufficient data should encompass one year to show any seasonal fluctuations if present.

   ii) It is pointless to combine observations from non-calibrated devices. On the other hand, it can be very useful to combine data from minimally-calibrated instruments.

   iii) It may be possible albeit not easy, to crowd-source calibrated data. It will be nearly impossible to crowd-source a meaningful analysis of that data.

f) Noise measurements from HF radio astronomers are available and extremely useful for noise floor studies.

g) The amount of data required depends on the question one wishes to answer. To know if the noise floor has changed in the last ten years, one must analyze the last ten years of HF radio astronomy data. If one wants to know the present noise floor in absolute terms, perhaps two weeks of calibrated data would suffice.

h) It is very easy to distinguish wideband Gaussian noise (natural cosmic noise) from terrestrial lightning and terrestrial man-made signals. The time-frequency signatures are often unique for each type of noise emitter. See Appendix 2 for examples.

   i) Noise can nearly always be characterized. Source identification is an ongoing project of the Spectrograph Users Group and requires knowledge of the offending emitter.[5]

   ii) Noise that is weaker than -10 dB relative to the galactic background may be ignored. This is as true for radio communications as it is for radio astronomy, since all users of the upper HF band must contend with the same galactic background emission.

We thank you for your attention.

If you have any questions, please contact us any time.

Respectfully,

Radio Jove / Spectrograph Users Group

Mr. Thomas Ashcraft, Heliotown Observatory, New Mexico
Mr. Jim Brown, Hawk's Nest Radio Observatory, Pennsylvania
Mr. Richard Flagg, WCCRO Observatory, Hawaii
Dr. Shing Fung, NASA Goddard Spaceflight Center, Maryland
Mr. Wes Greenman, Radio Alachua Observatory, Florida
Dr. Chuck Higgins, Middle Tennessee State University, Tennessee
Mr. Todd King, University of California Los Angeles, California
Dr. Andrew Mount, Mountain Rest Observatory, South Carolina
Mr. Whitham Reeve, Cohoe Radio Observatory, Alaska
Dr. Francisco Reyes, University of Florida, Florida
Mr. Jim Sky, Kentucky Radio Observatory, Kentucky
Dr. Jim Thieman, University of Maryland, Maryland
Mr. Nathan Towne, Towne Observatory, Ohio
Mr. Dave Typinski, AJ4CO Observatory, Florida (*primary SUG contact*)

[5] For examples of source identification, see http://www.radiojove.org/SUG/RFI/RFI.html

APPENDIX 1

Characteristics of the Galactic Noise Background.

The galactic noise observed in the HF band varies over the course of one day as the plane of our galaxy moves across the sky as the Earth rotates. Therefore, the galactic noise in a direction away from the plane of the galaxy, toward the galactic north or south pole, is used as a reference. This noise is immutable and easily measurable with simple, calibrated instrumentation.

The polar galactic background noise is therefore a useful reference against which other sources of noise in the HF band can be compared and the best reference for noise floor studies in the HF band. Figure 1 shows how the amplitude of the galactic background noise in the HF band changes with radio frequency.

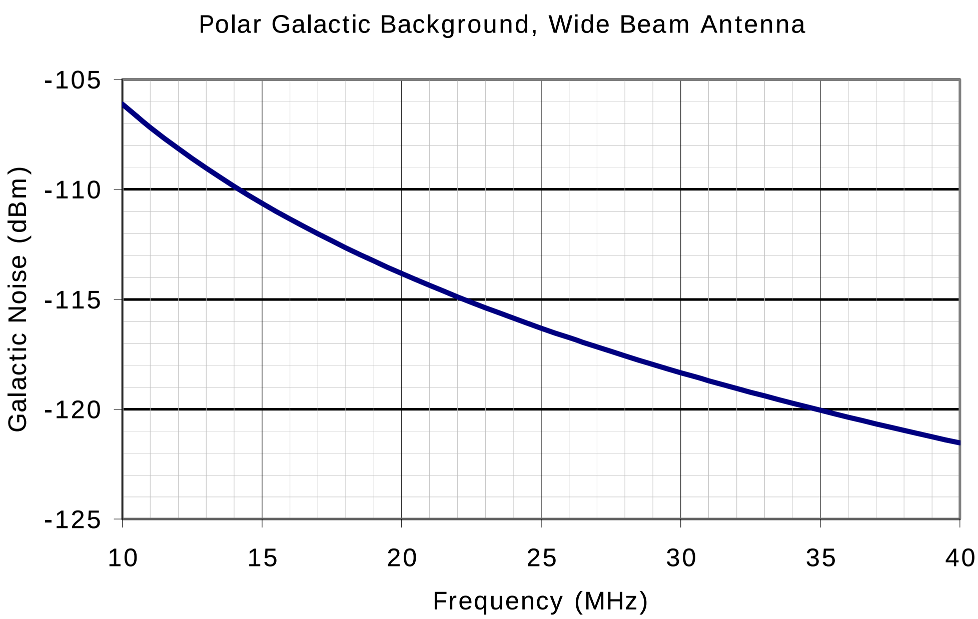

Figure 1 – Strength of the galactic background emission in the direction of the north or south galactic poles for a receiver pre-detection bandwidth of 6 kHz.[6,7,8]

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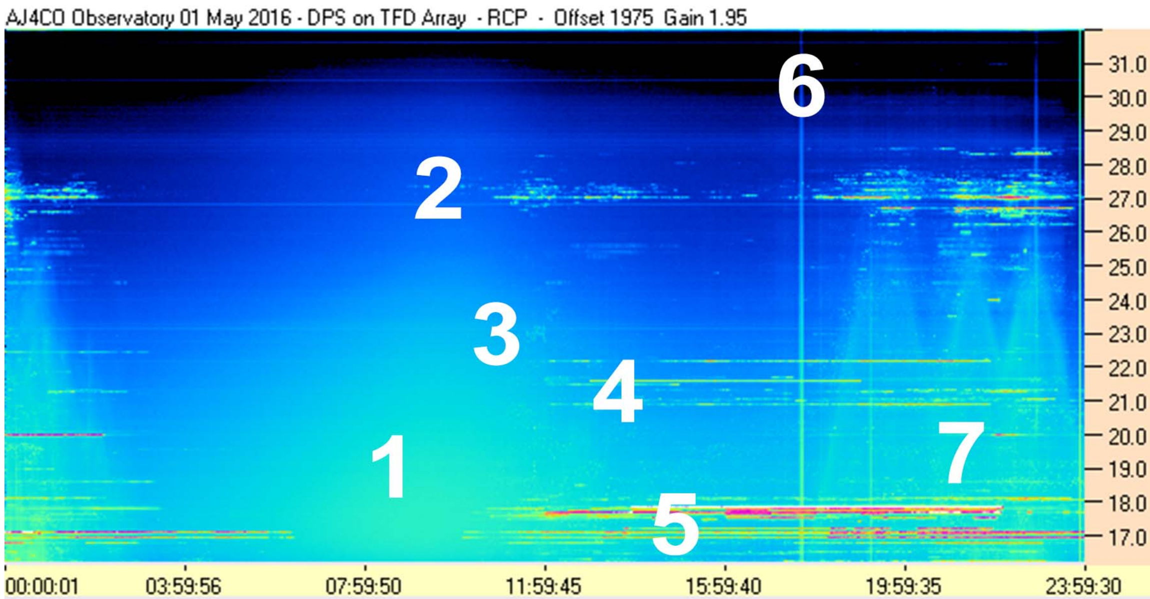
[6] Cane, H., *Spectra of the Non-Thermal Radio Radiation from the Galactic Polar Regions*, MNRAS 189, 465-478 (1979).
[7] Dulk, G., *Calibration of Low-Frequency Radio Telescopes Using the Galactic Background Radiation*, A&A 365, 294-300 (2001).
[8] Ellingson, S., *Antennas for the Next Generation of Low-Frequency Radio Telescopes*, IEEE Transactions on Antennas and Propagation 53, 2480-2489 (2005).

APPENDIX 2

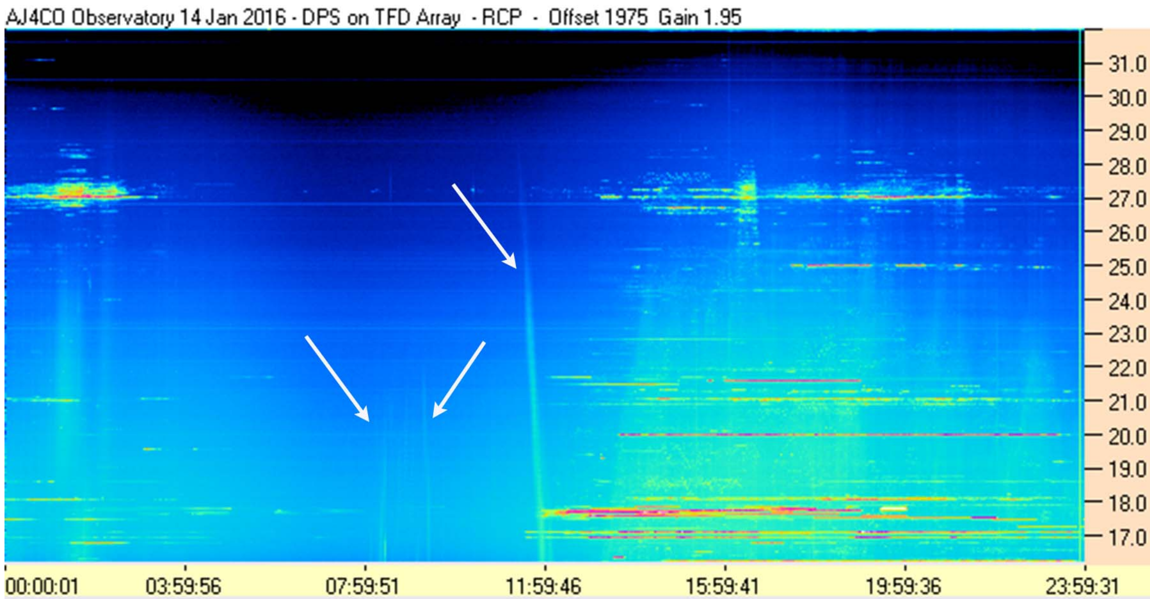
Examples of Noise Visible in Radio Spectrograms

The annotated spectrograms below are an example of how it is possible to most often identify the type of radio noise by its visible time-frequency signature.

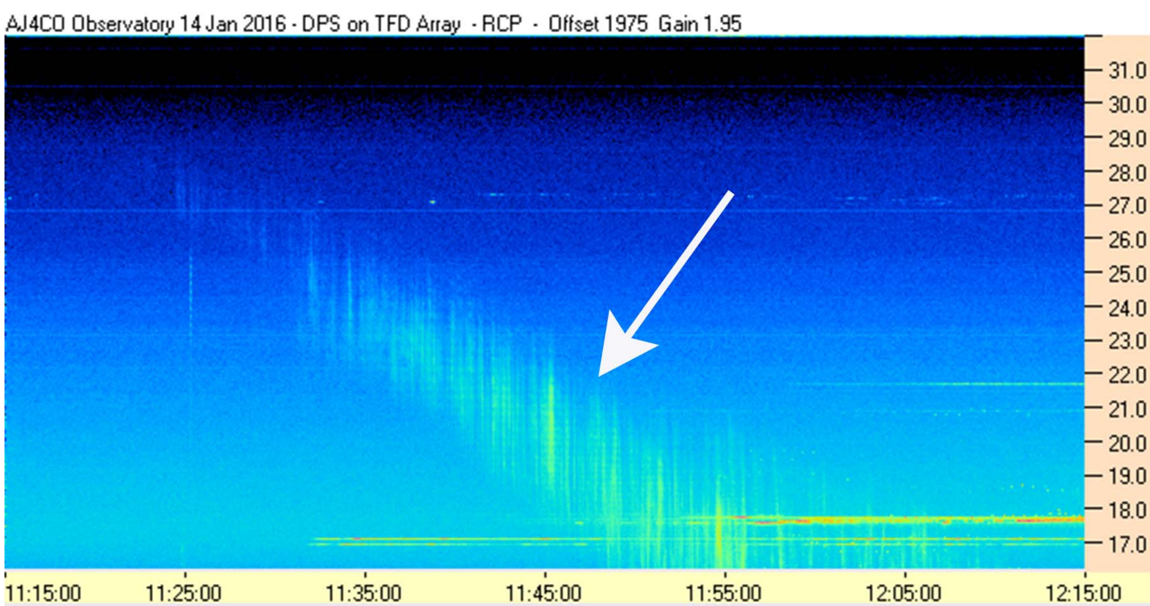
In the spectrograms below, the horizontal axis represents time in UTC, the vertical axis represents radio frequency in MHz, and color represents observed signal strength.



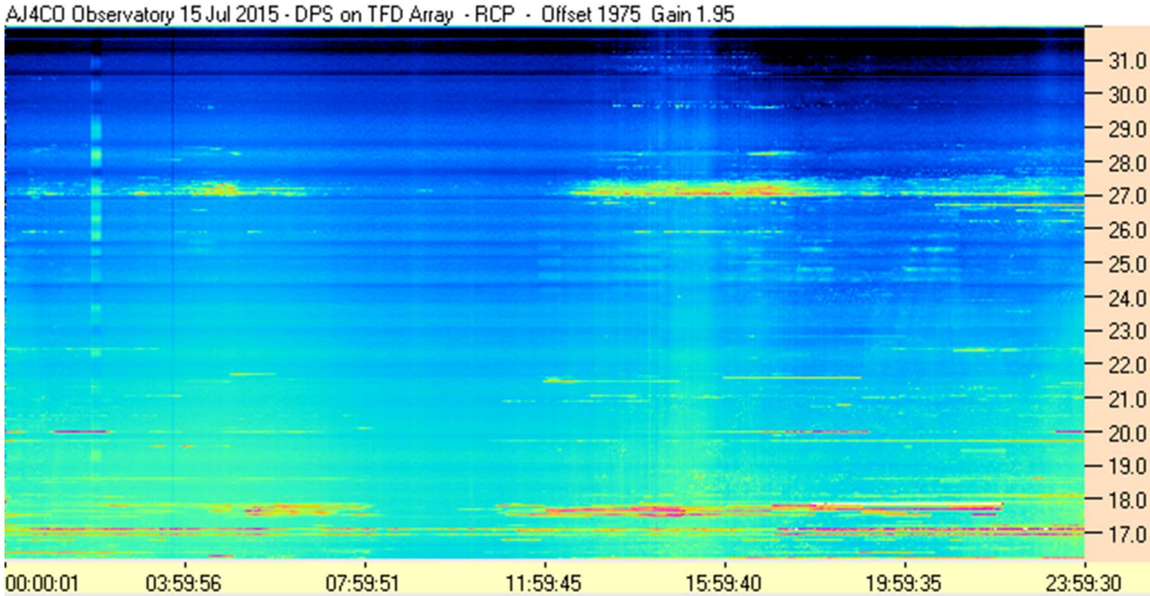
Spectrogram 1 – A 24 hour spectrogram of the upper HF band on 01 May 2016. Numbers indicated the following emission signatures:
1 – Gradual brightening and decay shows the galactic plane passing overhead.
2 – Horizontal lines show citizen's band radio communications.
3 – Small dots indicate HF radar emission.
4 – Horizontal lines show amateur radio and shortwave broadcast signals.
5 – Horizontal lines show shortwave broadcast signals.
6 – Vertical line shows a solar radio burst.
7 – Three triangular, teepee-shaped, overlapping areas show time-varying increase in so-called "band noise" due to terrestrial ionospheric propagation effects enabling natural emission from distant lightning to be received at the observatory.
Data courtesy of Dave Typinski, 2016.



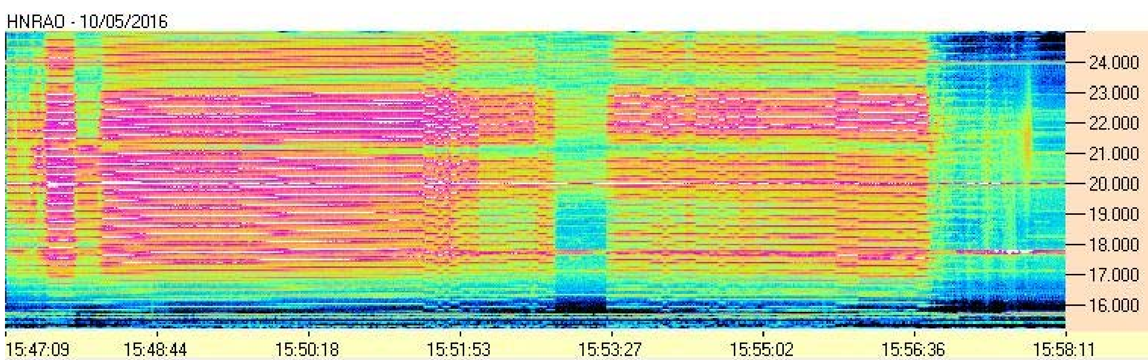
Spectrogram 2 – A 24-hour spectrogram; white arrows indicate radio emission from the planet Jupiter. Data courtesy of Dave Typinski, 2016.



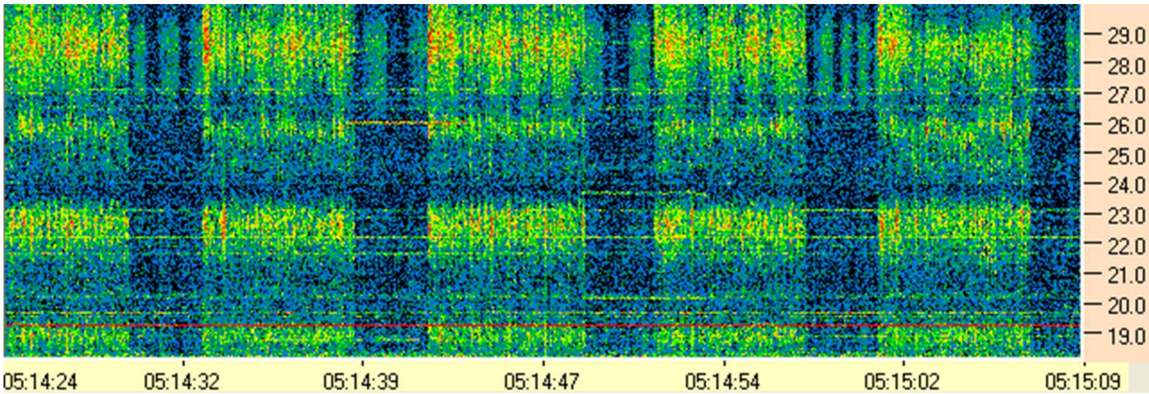
Spectrogram 3 – A 1-hour spectrogram; white arrow indicates radio emission from the planet Jupiter visible for approximately 45 minutes; this is a zoomed-in view of Spectrogram 2. Spectrograms 4 through 7 show how an increase in the noise floor can swamp Jovian emission. Data courtesy of Dave Typinski, 2016.



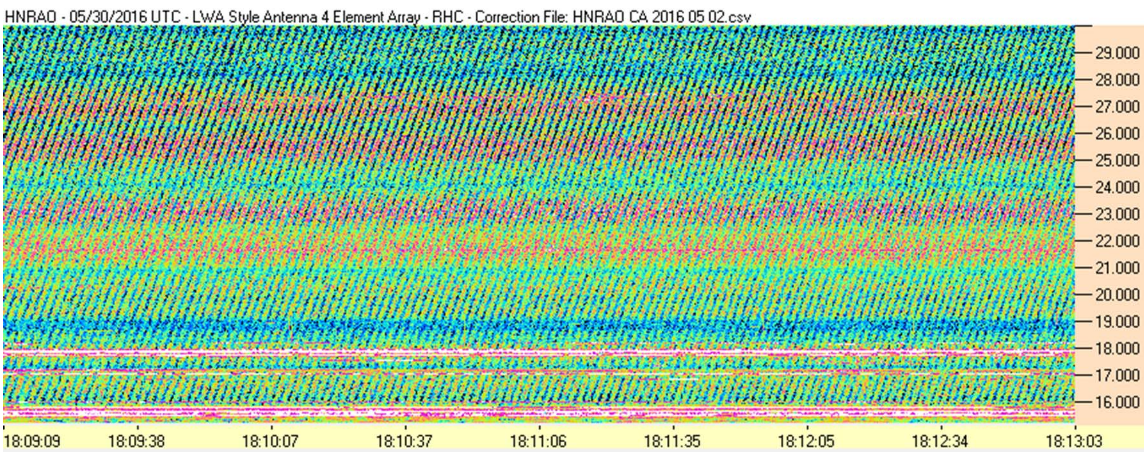
Spectrogram 4 – A 24-hour spectrogram showing unintentionally radiated moderate power line noise throughout the day visible as horizontal banding in the image. This weak power line noise makes radio astronomy for the planet Jupiter very difficult. Data courtesy of Dave Typinski, 2015.



Spectrogram 5 – An 11-minute spectrogram showing strong unintentionally radiated noise from a utility-pole-mounted cable TV system amplifier switch-mode power supply one quarter mile from the radio observatory visible as strong horizontal bands. This level of noise makes all HF radio astronomy completely impossible. Data courtesy of Jim Brown, 2016.



Spectrogram 6 – A one–minute spectrogram showing unintentionally radiated noise from a Maytag Neptune washing machine visible as strong vertical bands. Data courtesy of Whitham Reeve, 2010.



Spectrogram 7 – A four–minute spectrogram showing unintentionally radiated noise from severe power distribution system component arcing visible as strong diagonal bands. Such arcing is most often caused by failed pole-mounted lighting arrestors. The angle of the diagonals results from the beat frequency between the spectrograph sweep rate and the 120 Hz pulse rate of the arcing. Data courtesy of Jim Brown, 2016.

Identification of intentional and unintentional noise sources may also be accomplished by looking at the dynamic spectra on different time scales and frequency ranges. Examples of identification of several noise emission sources are available on the SUG Radio Frequency Interference (RFI) web page.[9]

[9] For examples of source identification, see http://www.radiojove.org/SUG/RFI/RFI.html

PUBLIC NOTICE

Federal Communications Commission
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Washington, D.C. 20554

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DA 16-676

Released: June 15, 2016

OFFICE OF ENGINEERING AND TECHNOLOGY ANNOUNCES TECHNOLOGICAL ADVISORY COUNCIL (TAC) NOISE FLOOR TECHNICAL INQUIRY

ET Docket No. 16-191

Comment Deadline: August 11, 2016

The FCC's Technological Advisory Council (TAC), an advisory group to the FCC operating under the Federal Advisory Committee Act, is investigating changes and trends to the radio spectrum noise floor to determine if there is an increasing noise problem, and if so, the scope and quantitative evidence of such problem(s), and how a noise study should be performed. In this public notice, the Office of Engineering and Technology (OET) announces the TAC's public inquiry, seeking comments and answers to questions below for the TAC about radio spectrum noise.[1]

TAC Noise Floor Technical Inquiry

The TAC is requesting input to help answer questions about the study of changes to the spectrum noise floor over the past 20 years. Noise in this context denotes unwanted radio frequency (RF) energy from man-made sources. Like many spectrum users, TAC members expect that the noise floor in the radio spectrum is rising as the number of devices in use that emit radio energy grows. However, in search for concrete evidence of increased noise floors, we have found limited available quantitative data to support this presumption. We are looking to find ways to add to the available data in order to answer important questions for the FCC regarding this topic.

Radio spectrum noise is generated by many different types of devices. Devices that are not designed to generate or emit RF energy but do so as a result of their operation are called *Incidental Radiators*. Most electric motors, light dimmers, switching power supplies, utility transformers and power lines are included in this category. There is little regulation governing the noise generated by these devices. Noise from such sources is expected to be minimized with "Good Engineering Practices."

Devices that are designed to generate RF energy for internal use, or send RF signals by conduction to associated equipment via connected wiring, but are not intended to emit RF energy, are called *Unintentional Radiators.* Computers and many portable electronic devices in use today, as well as many new high efficiency lights, are included in this category. Current regulations limit the levels of emitted RF energy from these devices.

Unlicensed Intentional Radiators, Industrial, Scientific, and Medical (ISM) Radiators, and Licensed Radiators are devices that are designed to generate and emit RF energy by radiation or induction. Cellular

[1] https://transition.fcc.gov/bureaus/oet/tac/tacdocs/meeting6916/TAC-Noise-Floor-Technical-Inquiry.pdf

phones and base stations, unlicensed wireless routers, Bluetooth devices, broadcast TV and radio stations, and radars of many types, are all examples of licensed / unlicensed intentional radiators, and microwave ovens, arc welders, and fluorescent lighting are examples of ISM equipment. Such emitters contribute to the noise floor with emissions outside of their assigned frequencies. These are sometimes generated as spurious emissions, including, but not limited to, harmonics of desired frequencies and intermodulation products. Regulations that permit the operation of these devices also specify the limits of emissions outside of licensed or allowed (in the case of unlicensed devices) frequencies of operation.

We are looking for responses to the following questions to help us identify aspects of a study to determine trends in the radio spectrum noise floor.

1. Is there a noise problem?
    a. If so, what are the expected major sources of noise that are of concern?
    b. What services are being most impacted by a rising spectrum noise floor?
    c. If incidental radiators are a concern, what sorts of government, industry, and civil society efforts might be appropriate to ameliorate the noise they produce?
2. Where does the problem exist?
    a. Spectrally
        i. What frequency bands are of the most interest?
    b. Spatially
        i. Indoors vs outdoors?
        ii. Cities vs rural settings?
        iii. How close in proximity to incidental radiators or other noise sources?
        iv. How can natural propagation effects be accounted for in a noise study?
    c. Temporally
        i. Night versus day?
        ii. Seasonally?
3. Is there quantitative evidence of the overall increase in the total integrated noise floor across various segments of the radio frequency spectrum?
    a. At what levels does the noise floor cause harmful interference to particular radio services?
    b. What RF environment data from the past 20 years is available, showing the contribution of the major sources of noise?
    c. Please provide references to scholarly articles or other sources of spectrum noise measurements.
4. How should a noise study be performed?
    a. What should be the focus of the noise study?
    b. How should it be funded?
    c. What methods should be used?
    d. How should noise be measured?
        i. What is the optimal instrumentation that should be used?
        ii. What measurement parameters should be used for that instrumentation?
        iii. At what spatial and temporal scales should noise be measured?
        iv. Should the monitoring instrumentation be capable of determining the directions of the noise sources? If so, how would those data be used?
        v. Is there an optimal height above ground for measurements?
    e. What measurement accuracy is needed?

    i. What are the statistical requirements for sufficient data? Would these requirements vary based on spectral, spatial and temporal factors?
    ii. Can measurements from uncalibrated, or minimally calibrated, devices be combined?
    iii. Is it possible to "crowd source" a noise study?

f. Would receiver noise measurements commonly logged by certain users (e.g. radio astronomers, cellular, and broadcast auxiliary licensees) be available and useful for noise floor studies?
g. How much data must be collected to reach a conclusion?
h. How can noise be distinguished from signals?
    i. Can noise be characterized and its source identified?
    ii. Is there a threshold level, below which measurements should be ignored?

Procedures

Interested parties may file comments up until the comment deadline indicated on the first page of this document. Comments may be filed using the Commission's Electronic Comment Filing System (ECFS). *See Electronic Filing of Documents in Rulemaking Proceedings*, 63 FR 24121 (1998).

- Electronic Filers: Comments may be filed electronically using the Internet by accessing the ECFS: http://fjallfoss.fcc.gov/ecfs2/.

- Paper Filers: Parties that choose to file by paper must file an original and one copy of each filing. If more than one docket or rulemaking number appears in the caption of this proceeding, filers must submit two additional copies for each additional docket or rulemaking number.
Filings can be sent by hand or messenger delivery, by commercial overnight courier, or by first-class or overnight U.S. Postal Service mail. All filings must be addressed to the Commission's Secretary, Office of the Secretary, Federal Communications Commission.

    - All hand-delivered or messenger-delivered paper filings for the Commission's Secretary must be delivered to FCC Headquarters at 445 12th St., SW, Room TW-A325, Washington, DC 20554. The filing hours are 8:00 a.m. to 7:00 p.m. All hand deliveries must be held together with rubber bands or fasteners. Any envelopes must be disposed of before entering the building.

    - Commercial overnight mail (other than U.S. Postal Service Express Mail and Priority Mail) must be sent to 9300 East Hampton Drive, Capitol Heights, MD 20743.

    - U.S. Postal Service first-class, Express, and Priority mail must be addressed to 445 12th Street, SW, Washington DC 20554.

People with Disabilities: To request materials in accessible formats for people with disabilities (braille, large print, electronic files, audio format), send an e-mail to fcc504@fcc.gov or call the Consumer & Governmental Affairs Bureau at 202-418-0530 (voice), 202-418-0432 (tty).

For further information, please contact TAC Spectrum and Receiver Performance working group co-chairs Greg Lapin, ARRL (GLapin@arrl.org) and Lynn Claudy, NAB (LClaudy@nab.org), or TAC working group FCC liaison Robert Pavlak, FCC Office of Engineering & Technology (Robert.Pavlak@fcc.gov